DIATOMS AS WATER QUALITY INDICATORS: PART I

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Abstract: A seven year study involving diatom collections and chemical analyses was conducted on the Nashua River, Fitchburg, Massachusetts. A comparison was made between three clean feeder streams and the highly polluted river, above and below the city of Fitchburg. Five diatom species were collected in the highly polluted area and are considered to be useful as water quality indicators for this specific water system.

Introduction:

Algae species have been widely used as indicators of water quality. One must approach the use of algae species as water quality indicators with some caution since the physical and chemical parameters of various aquatic systems are key factors in determining which species are present and pollution indicators in one environment may not serve for all situations. In his report of 165 studies, Palmer [1] listed the 80 most pollution-tolerant species of algae. Included in this list were 21 species of diatoms that could be considered water quality indicators. In this paper which is a summary of a seven year study (1967-1974) of the highly polluted Nashua River, an attempt is made to identify pollution tolerant species of diatoms and to examine their value as water quality indicators.

The Study Area:

The Nashua River is a tributary of the Merrimack River located in New England. The Nashua River drains an area of 450 square miles in the north Worcester County area of central Massachusetts and 88 square miles in the south central section of New Hampshire. The overall gradient of the river is shallow, dropping 527 feet over its 51 mile length. The bedrock of the area is composed of granite (and related igneous rocks) and metamorphic rocks such as shist and gneiss. The surface geology is a complex of weathered bedrock and glacial deposits including sand and gravel deposits in the form of outwash and drumlins. More than 75% of the basin is covered with second-growth mixed coniferous-hardwood forest. The above factors contribute to an overall acidic nature of the water in this region. The specific study area was the north branch of the Nashua River which has five small feeder streams that arise in the foothills of the 2000 foot Wachusett Range. These streams are rather clean and are not considered polluted and provide good trout fishing waters. As the feeder streams combine to form the Nashua River at Fitchburg, Massachusetts the water is utilized by a large number and wide variety of industries including paper mills, plastic and metal finishing factories. These industries along with and out-of-date sewage disposal facility for the city of Fitchburg, (pop. 40,000) impose a heavy load of pollutants and drastically change the character of the river. For the purpose of this study, three of the rather clean feeder streams were selected for collection sites and one collecting station was established on the Nashua River below the city of Fitchburg. This design was to facilitate the comparison study of diatoms in clean and polluted water. Collection sites were located on Phillips Brook, Old Mill Brook, and the Whittman River above the city of Fitchburg and at the point where the Nashua River crosses Massachusetts Route #2 below the city of Fitchburg.

Methods:

Routine chemical and physical examination of the water has been made over a period of seven years. A Hach Engineers Portable Water Testing Laboratory (Model Dr-El) was used. The Millipore filter coliform technique was used for bacteria study. The five day, 20^{o}C B.O.D. technique was used for Biological Oxygen Demand data. The chemical and physical parameters vary greatly with the season, water level and most of all the day to day activity of the various industries. In table 1, these data are presented.

Table 1 - Physical and Chemical Data

	Nashua	Old Mill	Whittman	Phillips
Dissolved Oxygen	0-12 ppm	6-14 ppm	6-14 ppm	8-14 ppm
	avg. 7	avg. 9	avg. 10	avg. 10
Water Temperature	3-25 C	0-20 C	0-21 C	0-20 C
	avg. 20	avg. 15	avg. 14	avg. 13
pH	5.5 - 7	6 - 7	6 - 6.5	6 - 7
CO_2	5 ppm	5 ppm	5 ppm	5 ppm
Total Hardness	30 ppm	50 ppm	50 ppm	45 ppm
Ca Hardness	26 ppm	33 ppm	37 ppm	40 ppm
Chloride	avg. 75	avg. 73	avg. 33	avg. 47
H_2S	trace	trace	trace	trace
Silica	2 ppm	0.2 ppm	0.1 ppm	0.1 ppm
Copper	.5 ppm	0.5 ppm	0.4 ppm	0.1 ppm
Iron	1.5 ppm	0.1 ppm	0.1 ppm	0.1 ppm
Turbidity (JTU)	105	5	10	0
Ortho-Phosphate	4.8 ppm	1.3 ppm	trace	trace
Nitrate	5-9 ppm	trace	trace	trace
B.O.D.	6-8 ppm	6 ppm	4 ppm	2 ppm
Coliform/50 ml	500+	230	56	18

Diatoms collections were made at the three feeder stream sites and at the Nashua River site. Rock and plant scrapings were made at each site along with diatometer samples, taken by placing the microscope slides in the diatometer for a period of seven days. The diatoms were "cleaned" by using the hydrogen peroxide-potassium dichromate method. The cleaned material was placed on #1 cover slips and mounted in Hyrax on microscope slides and studied under oil immersion. The species list, Table 2, is based upon 500 to 800 diatom counts per slide, thus they are expected to represent at least 80% of the taxa present.

Table 2: Nashua River Diatoms

Key: 1 = Nashua R. 2 = Old Mill 3 = Whittman 4 = Phillips

Achnanthes affinis (1,2,3,4)
Achnanthes diflexa (2,4)
Achnanthes exigna constricta (4)
Achnanthes hungarica (1)
Achnanthes lanceolata (2)
Achnanthes lanceolata lanceolatoid (3,4)
Achnanthes linearis pusilla (4)
Achnanthes marginulata (4)
Amphora ornata (2)
Amphora ovalis affinis (2)
Anomeoneis serions brachysira (3)
Asterionella formosa (1,2,3,4)
Cocconeis placentula (2)
Cocconeis placentula lineata (4)
Cocconeis placentula euglypta (2,3,4)
Cyclotella glomerata (2)
Cyclotella meneghiniana (1,2,4)
Cyclotella stelligira (2,3,4)
Cymbella amphicephala (3)
Cymbella aspera (2,3,4)
Cymbella turgida (2)
Cymbella ventricosa (1,2,4)
Diatoma anceps (4)
Eunota arcus (1,2)
Eunota curvata (1,2,3,4)
Eunota curvata capitata (3)
Eunota didon (4)
Eunota fallax (3,4)
Eunota hexaglyphis (3)
Eunota monodon (2,3,4)
Eunota pectinalis (2)
Eunota pectinalis monor(1,2,3,4)
Eunota perminuta (4)
Eunota serra (3)
Eunota tridentula perminuta (2)
Fragilaria construens (2,4)
Fragilaria crotonensis(134)
Fragilaria pinnata (3,4)
Fragilaria construens venter (3)
Fragilaria vaucheriae(1,2,4)
Fragilaria virescens (2,3,4)
Frustulia rhomboides capitata (2,3,4)
Frustulia rhomboides saxonica (2,3,4)
Frustulia rhomboides (4)
Frustulia rhomboides viridula (1,2)
Gomphonema angustatum major (2,3)
Gomphonema angustatum sarcophagus (2)
Gomphonema constrictum capitata (4)
Gomphonema parvulum (1,2,34)
Melosira granulata (1,2,3,4)
Melosira varians (4)
Meridion circulare (1,2,3,4)
Navicula cocconeiformis (4)
Navicula cuspidata (1,2)
Navicula lacustris (3,4)
Navicula lanceolata (1234)
Navicula minima (1,2,3,4)
Navicula placenta (2)
Navicula pupula elliptica (3)

Table 2 (continued)

Navicula pupula rectangularis (2)
Navicula scutiformis (3)
Navicula rhynchocephala(1,2,3,4)
Nedium affine (4)
Nedium bisulcatum balcalense (3,4)
Nitzschia amphibia (1)
Nitzschia dissipata (1,2,4)
Nitzschia filiformis (1,2,3,4)
Nitzschia palea (1,2,3,4)
Nitzschia recta (2)
Nitzschia romona (4)
Nitzschia thermalis (2)
Pinularia biceps petersinii (1,2,3,4)
Pinnularia microstauron (1,2)
Pinnularia brebissonii (3,4)
Pinnularia obscura (3,4)
Pinnularia subcapitata (3)
Pinnularia viridis (2,3)
Stauroneis anceps (4)
Stauroneis anceps gracilis (3,4)
Stauroneis phoenicenteron (134)
Stephanodiscus hantzschia(2,4)
Surirella angustata (1,2)
Surirella birostrata (3,4)
Surirella delicatissima (2,4)
Surirella linearis (4)
Surirella moelleriana (4)
Surirella ovalis (1)
Surirella ovata pinnata (1)
Surirella tenera (2,3,4)
Synedra parasitica (2)
Synedra rumpens (1,2,3)
Synedra rumpens fragilorioides (2,4)
Synedra rumpens meneghiniana (2,4)
Synedra rumpens var. (1)
Synedra ulna (2,4)
Synedra ulna subaequalis (1,2)
Tabellaria fenestrata (3,4)
Tabellaria flocculosa (1,2,4)

Results:

99 diatom species were identified from the collections made at the four sites and are listed in Table 2. As expected, some of the species found in the feeder streams were also collected in the Nashua River, indicating that some of the diatoms are constantly being washed down stream. Five diatom species were identified *only* from the Nashua River collections and are thus assumed to be the best water quality indicators for this specific water system. They are, *Achnanthes hungarica*, *Nitzschia amphibia*, *Surirella ovalis*, *Surirella ovata pinnata*, and *Synedra rumpens*. The most striking feature of the physical and chemical data is the fact that the water is always pH 7.0 or lower, total hardness is low and biological oxygen demand in the Nashua River borders on the value of the dissolved oxygen available.

Table 3 shows a comparison of diatoms that were indicated on Palmers [1]list of most pollution-tolerant species and those found in the Nashua River only, the feeder streams of the Nashua and from two diatom collection locations in Iowa (from [2]Christensen and [3]Gudmundson). It should be noted that the two streams studied in Iowa showed many of the pollution-tolerant species reported by Palmer. The Iowa streams were alkaline and exhibited much higher hardness readings than the

New England waters. Seven of the species reported by Palmer as pollution-tolerant species were collected in the clean feeder streams of the Nashua River system and only one, Surirella ovata, was found to be located in the highly polluted Nashua River.

Table 3: Comparison of Pollution-Tolerant Diatom Species

Diatoms from the 80 most pollution-tolerant species reported in 165 studies. C.M. Palmer-1969	pollution tolerant species in Nashua River	Nashua feeder streams	Iowa Stream Christensen	Iowa Stream Gudmundson
Nitzschia palea		x	x	x
Synedra ulna		x	x	x
Melosira varians			x	
Cyclotella meneghiniana		x	x	x
Nitzschia acicularis			x	x
Navicula cryptocephala				x
Gomphonema parvulum		x	x	x
Hantzschia amphioxys				x
Stephanodiscus hantzschi				x
Surirella ovata	x	x	x	x
Melosira granulata		x		x
Diatoma vulgare			x	x
Navicula viridula			x	x
Synedra acus				x
Cocconeis placentula			x	
Nitzschia sigmoidea			x	x
Achnanthes minutissima				
Cymatopleura solea			x	x
Fragilaria crotonensis		x		x
Navicula cuspidata		x	x	x
Fragilaria capucina				x

Conclusion:

Apparently diatoms can be utilized as water quality indicators, however the special physical and chemical characteristics of any given water system will dictate what species are valuable as indicators. One should not depend upon universal lists of water quality indicator organisms, specific lists should be developed for the systems under study. This Nashua River study site will continue to be an important area due to the fact that 17 million dollars is being expended by local, state and federal agencies to construct two large sewage and waste water treatment plants for the Fitchburg area. Upon completion of these facilities and the expected dramatic change in the water quality of this system, a true test of the here-in mentioned diatom species as water quality indicators will be possible.

Literature Cited

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